# Technological Change in Agriculture in the Yucatán Peninsula: Implications for Deforestation and Climate Change Policy

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# Brief Introduction to the Study Area and Research Objectives

- **Area of Study.** Southern Yucatán Peninsula region of Mexico, home to most extensive tracts of tropical forest remaining in Mexico.
- **Research Objectives.**
  - Understand causes of deforestation in the region with emphasis on the role of technological change.
  - Develop economic and statistical models that advance the methodological frontier.
  - Forecast future deforestation patterns.
  - Inform policymakers, especially vis-à-vis global climate change policy.

# Presentation Outline

1. **Introduction.**

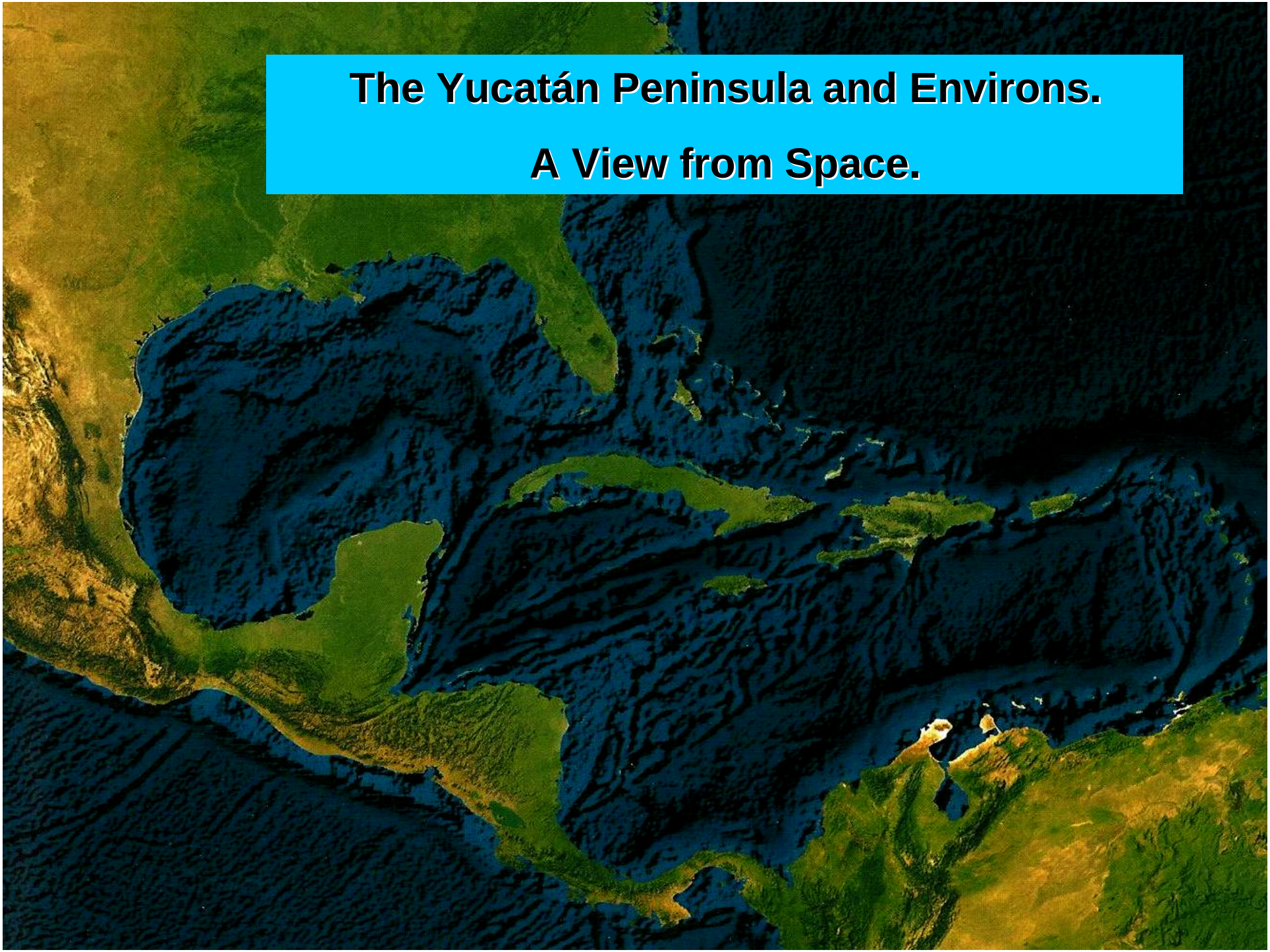
   Profile of the study area including the socioeconomic landscape.

- **Policy objectives.**
- **Research methods.**
  - Economic Theory.
  - Statistics.
  - Survey Design and Implementation.

4. **Conclusion:** Current and Future Work.

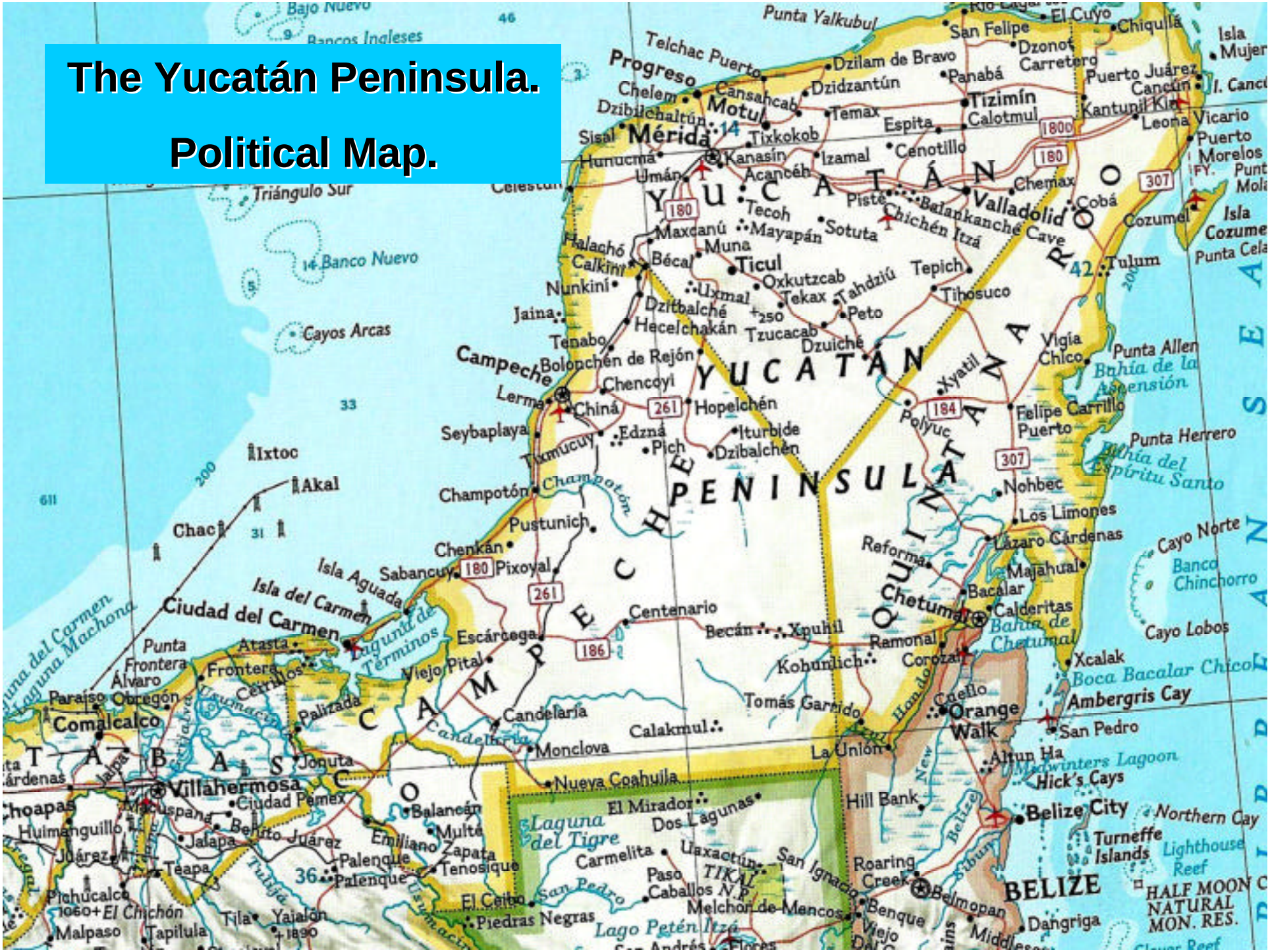
# Introduction to the Study Area as Context for the Research

- Geographic orientation.
- The socioeconomic landscape.
- The agriculture—deforestation link.
- Aspects of technological change.


The Yucatán Peninsula and Environs.
A View from Space.

# The Yucatán Peninsula.

# Political Map.



# The Economy of the Southern Yucatán – Mainly Agricultural

- Agricultural production by small-scale family farmers is far and away the primary economic activity in the region.
- Farmers practice shifting agriculture (e.g. slash and burn). Clearing trees and burning them enriches the otherwise nutrient poor soil.
- Traditional subsistence crops are maize, squash, and beans.
- Many farmers have in recent years started growing jalapeño chili peppers, the first cash crop to be widely adopted.

# The Agriculture - Deforestation Link

- Agriculture is the prime economic activity and main land use in the region. Increased agricultural land use equals increased deforestation.
- Government agencies and non-government organizations promote a vision of the region as a archeological-ecological tourism zone.
- Farmers, faced with poverty, resist constraints on how they choose to use their land.

# Key Trends in Agriculture and Deforestation

- Deforestation rates are increasing as farmers cultivate a larger fraction of their land holdings (with shifting agriculture, only some percentage land is always under forest).
- There appears to be a link between the increasing pursuit of commercial production for export out of the region and increased deforestation.
- Intuitively this makes sense– add commercial objective on top of subsistence production and area of cultivation will increase. My research seeks to prove or disprove a causal link.

# Focus on Technological Change in the Agricultural Sector

- Define technological change in agriculture as adoption of new crops or new production methods.
- Three aspects to the technological change on-going in the region.
  - The continued, albeit uneven, diffusion of jalapeño chili peppers (the region's main cash crop).
  - New production methods: use of agrochemicals, mechanization, irrigation, changing fallow cycles. (Prior to jalapeños, no "modern" inputs.)
  - Emergence of new commercial alternatives.

# Key findings of preliminary fieldwork

- At least stagnation, or decline, in chili production (in % of farmers and area cultivated).
- Emerging alternatives evident.
- Observation that the future of the region is diversification (frequent characteristic of a modern economy). Region has potential as a supplier of high-value winter crops to other parts of Mexico and foreign markets.

# Emerging Technologies

- Papaya.
- Agroforestry.
- Intensive livestock production.
- Silviculture.

# Current Situation for Jalapeño Chili Pepper Cultivation

- One important observation during preliminary fieldwork – jalapeño chili remains the key, but expansion of the crop has given way to stagnation and decline.
- A better understanding of the Jalapeño chili story can still give important insight into behavior in general and intensification in particular.
- Have more slides on this if we want to talk more about the jalapeño chili peppers story.

# The Mechanization Factor

- Though all farmers use agrochemicals to grow chili, only 30% are mechanized.
- Productivity differential: Mechanized chili farmers produce about 50% more per hectare.
- Land use differential in area of chili grown: Mechanized 1.7 hectares, Not Mech. 1.2.
- Income and wealth constraints seems to be the main reason we do not see greater diffusion of mechanization.

# Technological Change in Agriculture and the Environment

- Does technological change equal technological progress (in net social terms; for the environment)? There exists debate about whether or not technological change in agriculture is necessarily good for the environment.
- Increased productivity means same amount of land feeds more people. Increased profitability means farmers have opportunity to afford environmental quality as a consumption good (starving people think first about feeding themselves).
- Increased profitability gives a greater incentive to clear land and reduces the effect of income constraints that may limit expansion of agricultural land.

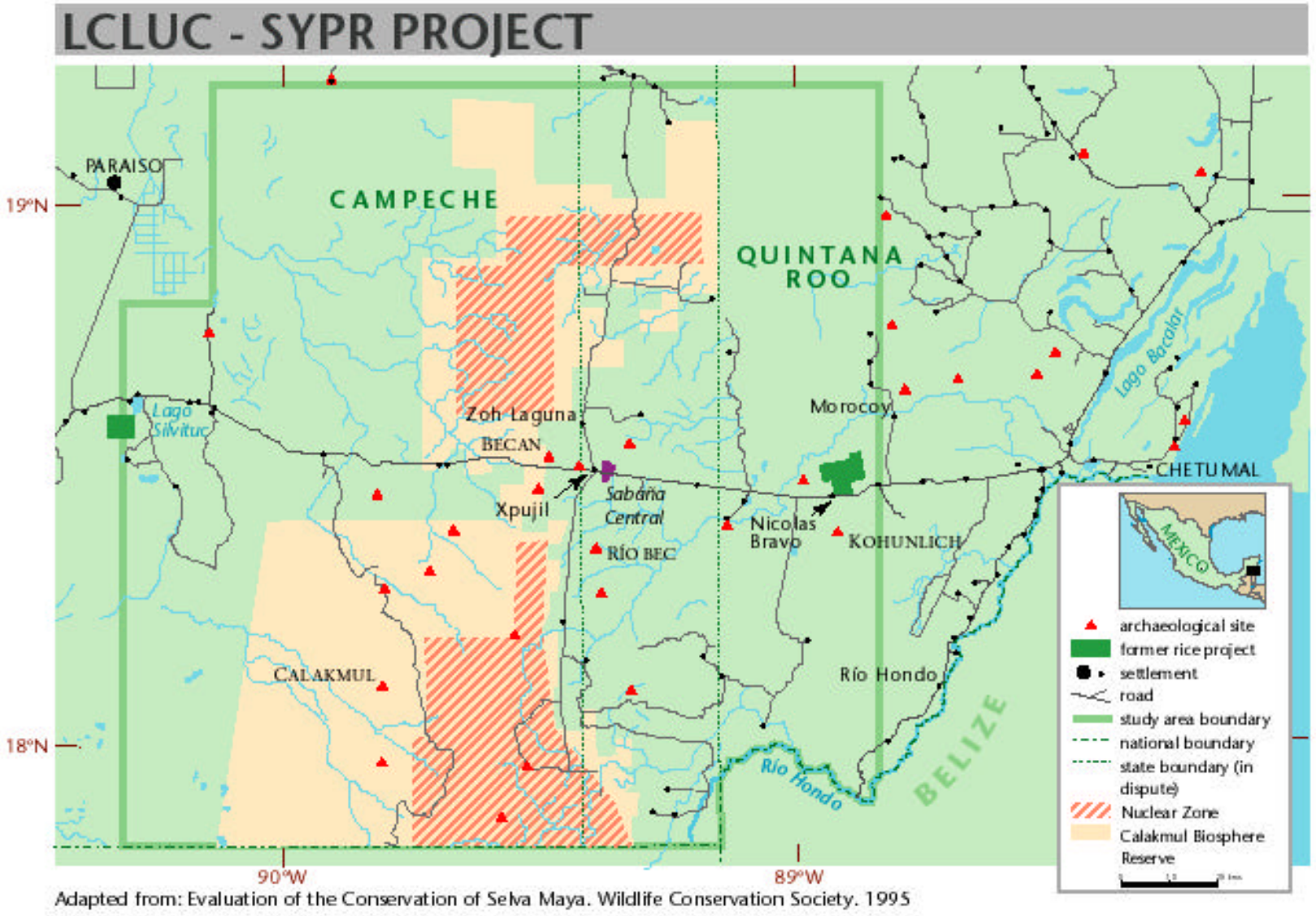
# Technological Change in Agriculture and the Environment

- Perhaps we can conclude:  Globally, increased productivity through technological change results in overall decreases in negative environmental impacts.
- At a local or regional scale, technological change in agriculture may increase or decrease environmental impacts depending on circumstances.
- If an agricultural product is for export (local demand not a limiting factor) and labor, capital, or biophysical constraints do not limit growth, technological change is likely to increase negative environmental impacts locally.

# A few final notes of context

- Recently received funding (a dissertation research grant) from the University of California's Institute for Mexico and the U.S. Funds will enable hiring of survey assistants, which will allow me to greatly increase sample size.
- Research is being conducted in partnership with a large scale NASA-funded project that has worked in the area for five years studying various perspectives on land use and land cover change.

# Southern Yucatán Peninsular Region
# As Defined By NASA Project




Adapted from: Evaluation of the Conservation of Selva Maya. Wildlife Conservation Society. 1995

# Policy Objectives

# Introduction to Policy Objectives

- Main policy objective is to shed light on a question that is the subject of controversy within the climate change policy community. What is the best role for land use projects in the Kyoto Protocol's Clean Development Mechanism?
- Important to explore in general the issue of the relationship between technological change and the environment (especially in the context of developing country agriculture).
- Also hope that a better understanding of the causes of deforestation and the direction implied by current trends will be useful to various people and institutions interested in the region's future.

# Definition of terms

- **Land use change:** A change in one type of human use of land or natural cover to another type. Includes deforestation. Abbreviation for the more technically accurate term land use and land cover change.
- **Model:** A mathematical representation of cause-effect processes.
- **Forecast:** A scenario depicting future events and their timing. For work here, forecasts will be based on models, and models will be based on empirical data from time past.

# Background to a Climate Change Policy Controversy

- A problem for policymakers – Yucatan forests have global environmental value (in climate stability and biodiversity), but local farmers cannot be expected to take these global benefits into account.
- One possible avenue to address this – payment to farmers for greenhouse gas (GHG) benefits of forest conservation under the Kyoto Protocol.
- Note that payment for GHG benefits of forests may be one of few win-win policy options in tropical frontier regions. (Win for living standard of local farmers and win for the environment, local and global.)

# Introduction to Flexibility Mechanisms

- Flexibility mechanisms may be called “cap and trade” programs. Sets a quantitative limit on pollution emissions but does not require uniform action.
- Example of $SO_2$ trading in U.S. Note the problem of hot spots when distribution of pollution matters.
- Kyoto Protocol includes three distinct flexibility mechanisms.

# Flexibility Mechanisms in the Kyoto Protocol

- **Three types of flexibility mechanisms**: (1) emissions trading; (2) joint implementation; (3) Clean Development Mechanism (CDM) projects.
- **CDM explained:** Investment from one country funds a GHG emission mitigation project in another country. Investor country is credited with GHG benefits resulting from the project. Allows Annex I countries to be credited for GHG emission reductions achieved in Annex II countries.
- **COP 6 (II) Decision.** In Bonn, during the summer of 2001, it was agreed that only afforestation and reforestation type land use projects will be allowed under the CDM for the first commitment period, until 2012. Explicit plan to reconsider this decision later.

# Advantages and Weaknesses of the Clean Development Mechanism

- **Advantages.** Potentially lower mitigation costs. Potential ancillary socioeconomic and environmental benefits for host country. May be be possible to achieve more substantial global mitigation efforts if costs are lower.
- **Weaknesses.** Technical challenges to accurate estimation of GHG benefits. Incentives to overestimate GHG benefits. Benefits may not last in the long term (particular concern with land use based projects). Perverse incentives.

# The Clean Development Mechanism – Types of Projects

- **Types of projects:** Renewable energy, energy efficiency, alternative fuels in transportation, land use.
- **Types of Land Use Projects:** Reforestation, afforestation, deforestation, sustainable agriculture and forestry projects.

# The Clean Development Mechanism – Points of Contention

- **CDM in general**– institutional issues such as approval process prior to implementation; monitoring and verification protocols after implementation; percentage of reductions allowed through CDM projects.
- **Land Use in particular**– ecological issues of measuring carbon; permanence of gains.
- My research seeks to shed light on the debate over the potential for accuracy in estimation of GHG benefits from projects (and in doing so touches on the issues of “baselines” and “spillovers”).

# Nuts and Bolts of GHG Benefit Estimation for Projects

- Two elements of a GHG Benefit Estimate are:
  - **Baseline scenario.** Future land use patterns anticipated given current trends (e.g. without the intervention contemplated by the project being assessed). See that this is counterfactual—not directly verifiable—once implementation has begun. Can do indirect verification with control plots.
  - **Project scenario.** Future land use patterns expected if a proposed project is implemented.
- Each scenario has a socioeconomic (land use forecast) and ecological (carbon content of different land use types) component.

# Approaches to Forecasting

- **Time series.** Deforestation rates as a function of time (not attempting to understand cause-effect process at work).
- **Structural.** Deforestation rates as a function of causal factors. Over the past decade, two strands of research have emerged in this category. The geographic strand has excelled at spatial analysis. The strength of the socioeconomic strand has been progress in understanding the underlying decision making processes.

# Costa Rica Case Study

- Mention briefly here a case study – review of the GHG benefits of a Costa Rican Forestry Project (slowed deforestation and enhanced reforestation).
- Project developers estimate, 15.7 Mt of C.
- Our best estimate, 8.9 Mt of C.
- In light of this study, and given incentives to overestimate benefits, we concluded an independent review board is needed.

# Policy Objectives – Scope of Current Work and Future Work

- For purposes of my dissertation, only seek to forecast a baseline scenario of future land use.
- Later forecast a project scenario use modeling results as basis for estimation of greenhouse gas (GHG) benefits of a project to be implemented by an environmental group, The Nature Conservancy.
- Compare results with those of Winrock International research team, which is assessing the Nature Conservancy's project using four different methods.

# Conclusion on Policy

- In research work, attempting to remain agnostic vis-à-vis the best policy on land use projects under CDM. Just seeking to understand the challenges and potentialities of forecasting land use patterns.
- Still, my non-scientific self has an opinion. I'm for exploring a broader definition projects allowed. Why? (1) Regardless of the means, it is an important for resources to flow to tropical forest conservation. (2) Land use projects under the CDM can serve as a useful interim measure as energy options continue to expand.

# RESEARCH METHODS

- Preface.
- Example of a Theoretical Model.
- Econometric Modeling.
- Survey Design and Implementation.

# Preface to Methods Discussion

- Note respective roles of quantitative and qualitative analysis in social science research.
- The economic approach to empirical research: develop stories of behavior that capture key features; give these mathematical interpretation; hypotheses to be tested statistically follow from the theoretical model.
- Theory as a precursor for statistics (differing opinions).
- Fuzzy boundary between statistics and econometrics . (No single accepted definition of econometrics. Key is managing the frequently encountered problems of an inability to conduct controlled laboratory experiments in social science.)

# Preface to Economic Theory Discussion

- Key role for the mathematical technique of constrained optimization in economic theory. Gives necessary and sufficient conditions that can be translated to concrete, testable statistical hypotheses.
- Increasing popularity of the alternative to an analytical solution, that is solution by simulation.
- Interesting trend toward incorporation of psychological insights.

# Explanatory Stories in the Works

- The role of risk (especially chili price risk) in behavior.
- Information transmission and learning as part of the process of technological change (touches on neighborhood effects, information externalities, peer effects). Note links to sociology literature.
- Choices on fallow cycling and changes with intensification.
- The future of emerging commercial alternatives (using agronomic models).
- Is there optimization according to a standard economic thinking.
- Compare performance of a model based on conventional economic optimization to a psychologically-inspired model.

# Example of a Theoretical Model

How risk affects farmers' behavior (land use and technological choice).

# Example of a Theoretical Model – Preliminaries

- The model developed here seeks to explain farmers' allocation of land among different crops in light of the price risk (variability over time) and differences among attitudes towards risk among households. Technological choice is

- Here, consider three crop options.
  - m: maize (the traditional crop)
  - c1: un-mechanized chili
  - c2: mechanized chili

- Am going to speed through technical details, but want to give the flavor of such a model.

# Example of a Theoretical Model (cont.)

- Model is known as portfolio model with risk, and is related to mean-variance models used in finance.
- The model incorporates the idea that people prefer certainty, or put differently that variability is costly (at least when it comes to an income flow; after all, variety is the spice of life).
- Assume that stochastic profits are normally distributed and can be characterized by their mean and variance.

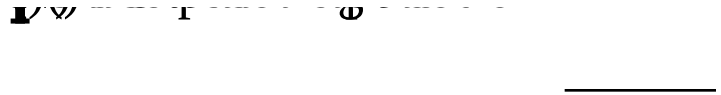
# Profits: Definitions and Assumptions

# Income:
# Definition, Expectations and Variances

# Decision Framework

- Assume that utility is a separable function of income and non-random leisure.
- Assume that expected utility from stochastic income takes a mean-variance form.
- So expected utility in a given time period is

- Assuming a forward looking agent, define the present value of EU



# The Constrained Optimization Problem

# The Lagrangian and First-Order Conditions

# Reduced-Form Equations

- First-order conditions are necessary conditions, and imply the following reduced-form equations for land area devoted to each crop.

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# Hypotheses:
# Some (A Priori) Hypotheses

- Will find risk aversion among household farmers in the study area, e.g. measures of absolute and relative risk aversion will be non-zero.
- The measure of absolute risk aversion will be shown to be a statistically significant variable in determination of land use.
- The budget constraint will bind (the multiplier will be significantly different from zero), but the land constraint will not bind (the multiplier will not be significantly different from zero).

# Econometrics

- Reduced form equations of demand for land for each crop type provide the link between the theoretical model and the econometric model.
- Here, theoretical work provides justification for variables included in statistical work.
- Note stronger links between theory and econometrics may possible and desirable (e.g. directly estimating one or more first order conditions).

# **Econometrics** (continued)

- Estimate a panel data model by parameterizing reduced form equation.
- Reason to suspect fixed effects based on village membership. Test fixed vs. random effects (Hausman test). A fixed effects model:

# **Econometrics** (continued)

- Will want to consider taking into account unobservable selection effects (entrepreneurial spirit).
- Do this via a two-stage Heckman procedure. Bring in a type of network effect. Suppose greater aggregate adoption reduces the fixed cost of adoption. Include this in the first stage probit on adopt chilies or not, but not in the land use equation.
- Stack the three equations and run as a system of Seemingly Unrelated Regression equations.

# Survey Issue: Sampling Strategy

- Employ a stratified, two-stage cluster sampling strategy.
- Ejidos (villages) as the first-stage unit and households as the second-stage unit.
- Stratify ejidos according to
  - the north-south rainfall gradient
  - access to Highway 186
  - older, land rich vs. newer, land poor.

# Survey Issue: Data Collection.

Categories of variables targeted for collection from each household:

- Land Use
- Profits (Revenue and Costs)
- Income, Wealth, and Credit
- Demographics
- Information dynamics
- Community

# CONCLUSION:
# Current and Future Work

- Continue to work on modeling issues.
- Finalize agreement with Clark University graduate student on survey cooperation.
- Draft survey instrument.
- Return to field:  pretest survey instrument; reach agreements with villages on participation.
- Begin survey implementation immediately after end of summer harvest, November 1, 2003.
- Return with data in hand by April 2004.
- Have some real results to show GCEP in summer 2004.

# Acknowledgement

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